Product Ideation by Persons with Disabilities: An Analysis of Lead User Characteristics

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ABSTRACT
Product dissatisfaction among persons with disabilities is not uncommon. Innovation theory suggests that dissatisfied users who stand to benefit from having their unmet needs solved, are likely to be product innovators. However, among disabled persons, little empirical research has thus far been done to determine their degree of ideation, or which characteristics are associated with product ideators. Within this study, we present results from a survey of 178 persons with disabilities, exploring their ideas for products. A panel of two expert judges evaluated their ideas based on user value, feasibility and originality. Using the total score of these three attributes, we used a hierarchical multiple regression model to explore which user attributes can be associated with the best ideas. Our results indicate that overall product dissatisfaction and academic degree ownership both effect idea quality. Furthermore, 12% of respondents also generated ideas that are relevant for non-disabled people.

CCS Concepts
• **User characteristics~People with disabilities**

Keywords
user innovation; lead users; idea generation

1. INTRODUCTION
The living and working environment is typically designed for persons without disabilities, with disabled persons having to rely on adaptations of products and existing technologies [18]. As a result, persons with disabilities often have difficulty with technology use [20], reporting high degrees of product dissatisfaction [48, 49] It is reasonable to expect that many persons with disabilities may also have needs that are not met by current products.

Older adults face similar issues [52]. For example, modern TV interfaces present visually impaired persons with many usability problems [15].

Additionally, disabled persons also face challenges when using assistive devices. According to Phillips and Zhao [48] 29.3% of users abandon assistive devices, while Ravneberg [49] notes that users "expressed great dissatisfaction with some of the [assistive] devices". As noted by Riemer-Reiss and Wacker [50], one reason for such high rates of abandonment may be limited consumer involvement. Literature on user driven innovation would suggest that such high product dissatisfaction may be associated with users producing their own innovations [7, 17, 45, 54]. Given that consumers are playing an increasingly important role in product innovation [6], it is also important to understand which users may be valuable innovators.

This aim aligns with calls for stronger involvement of patients [56], with the goal of increasing their welfare [19] and improving the quality of patient care 12]. Allarakhia [1] argues that "lead patients" are important stakeholders within healthcare, and that more must be done to engage patients as part of treatment and rehabilitation strategies. Furthermore, providing disabled persons with more support, improves functional capabilities, with associated benefits [36].

However, there has been little research done on product-ideation among persons with disabilities, despite studies highlighting the prevalence of user driven innovation among general consumers [27, 31]. In this paper, we will examine the rate of ideation among persons with disabilities. Additionally, we will examine which characteristics can be associated with users who proposed high quality ideas. Finally, our study looks at how many submitted ideas could also be considered valuable for non-disabled people.

The remainder of this article is structured as follows: in section 2 we will provide more background on user driven innovation, and characteristics associated with innovative users. Section 3 will present and discuss our method, while section 4 will present our results. We discuss our findings in section 5.

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2. BACKGROUND

While user driven innovation is well established [6], a central concern within the research on user innovators remains finding users before they have innovated, i.e.: determining which characteristics user innovators have [8, 9, 40].

Research on user driven innovation has typically focused on so-called lead users, introduced by Von Hippel [29]. Two user characteristics play an important role in defining them. First, they have needs that are not yet met, while also being in a position to benefit when their needs can be solved [29]. Scholars have proposed certain proxy measures through which to identify such lead users [59]. Within this study, we will build on these proxy measures.

The idea that persons with disabilities can be product innovators has also previously been raised. A prominent example is a study by Franke and Shah [23], where a community of cyclists with amputated arms modified the breaking systems of their bicycles to better suit their needs. Or selection and involvement of a single lead user [14] as part of the development process of an assistive mobile device for obstacle detection. This approach is related to a case presented by Leahy [38] who argues for "targeted consumer involvement" during the development of an assistive device for deaf persons. The author stresses that particular users, i.e.: with certain characteristics, are valuable during the design process.

Additionally, persons with disabilities may have unique experiences with product use due to their disability. Furthermore, assistive devices could also prove beneficial to persons without disabilities. To illustrate, Manresa-Yee et al. [44] presents a vision based interface for persons with motor impairment that can also be used by regular consumers. Brodwin, Star, & Cardoso [10] discusses several computer peripherals intended for persons with disabilities, but which can also be valuable to non-disabled people, including hands-free input devices, or eye tracking.

These and other examples describe the involvement of disabled persons in the design process (for an overview see [13]). Cases frequently employ participatory design strategies, with end-users co-designing solutions (often assistive devices) using simple material such as clay [14], or rapid prototyping techniques such as 3D printing [16].

Such participatory driven approaches differ from the current study, as their goal is to closely involve end-users in product development, where a designer or researcher is developing assistive device. While they illustrate the value of user involvement in the design process, they do not address the degree of user driven innovation by disabled persons, or whether the concepts generated by end-users can be valuable for non-disabled people.

We focus in this paper thus not the development of methods for user involvement, but rather to explore the degree of ideation among disable persons, and the characteristics idea generators will have within the cohort of disabled persons. As a result, in this article we concentrate solely on users who have their own ideas, disregarding the role any intervening designers.

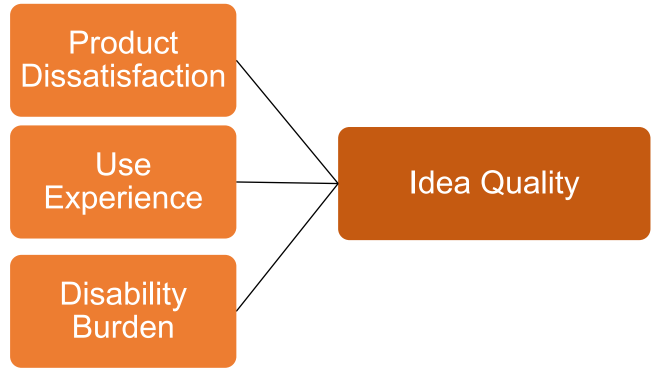

Figure 1. Conceptual Model

2.1 Common User Innovators Characteristics

Our aim in this study is two-fold. First, we want to measure the incidence of product ideation among persons with disabilities, followed by the identification of characteristics that can be associated with idea generators.

To determine which characteristics to consider, we will briefly review prominent user characteristics associated with user innovators.

First, as originally proposed by Von Hippel, users who innovate are typically doing so because they have some product need that is not yet met [29]. By extension, they seem to be dissatisfied with current products. As a result, several authors have proposed that product dissatisfaction can be associated with user innovators [7, 17, 23, 45, 54]. Given this, we propose H_1:

H_1: Product dissatisfaction is positively associated with idea quality

Use experience is typically associated with user innovators [7, 22, 39, 53, 54]. Use experience may refer to repeated use in a particular context, i.e.: prolonged experience with IT system use as a visually impaired person. Being longer acquainted with a product, or service may thus reveal problems not known to average users. Simultaneously, product use may be taking place under challenging or novel environments, which could be the case for persons with disabilities. We propose H_2:

H_2: Use experience is positively associated with idea quality

Finally, Urban & von Hippel [59] propose defining measures of benefit to locate innovative users. When a user is in a position to benefit most from an idea, they are more likely to be a user innovator [23, 29, 47, 51]. Such measures of benefit are likely to be domain specific [28, 29]. What can be viewed as beneficial for the development of software [47], will not necessarily be beneficial in the domain of sports [23]. In the specific context of our study, we hypothesize that the disability burden experienced by a participant is a measure of benefit, whereby persons with a higher disability burden will be more likely to benefit from a new product, and thus be more likely to innovate. From this follows H_3:

H_3: Disability burden is positively associated with idea quality

Our research hypothesis is summarized in figure 1.

Table 1. Pearson Correlation Coefficients

	I	II	III	IV	V	VI	VII	VIII	IX	X
Idea user value (I)	1,00									
Idea feasibility (II)	0,01	1,00								
Idea originality (III)	0,01	-0,41**	1,00							
Idea quality (IV)	0,66**	0,39**	0,43**	1,00						
Idea relevance for non-disabled users (V)	-0,12	-0,06	-0,08	-0,17	1,00					
Age (VI)	0,16	0,15	-0,23*	0,04	0,03	1,00				
Gender (VII)	-0,02	-0,13	0,18	0,03	0,29*	-0,10	1,00			
Academic degree (VIII)	0,21	-0,06	0,26*	0,28*	0,01	-0,03	0,01	1,00		
Disability duration (IX)	0,01	0,17	-0,07	0,07	0,15	0,35**	0,08	-0,03	1,00	
Disability burden (X)	0,15	-0,06	0,00	0,06	0,08	0,04	0,15*	-0,10	0,07	1,00
Dissatisfaction (XI)	0,5**	0,10	0,20	0,54**	-0,04	0,08	-0,04	0,05	-0,01	0,34**

** Correlation is significant at the 0,01 level (1-tailed).

* Correlation is significant at the 0,05 level (1-tailed).

3. METHOD

3.1 Data collection

One aim in this study was to examine which characteristics are associated with innovative idea generation among persons with disabilities. To do so, we performed a survey among 178 disabled persons, asking them to provide details about their disability (accessible via http://goo.gl/l0CLe3). As part of the survey, we also asked them if they had an idea to modify or create something for themselves. Note, these results focused on ideas only, i.e.: concepts that were not realized by participants.

Our online survey was distributed between February and April 2016 with the help of 5 organizations for disabled persons, notably the visually impaired, hearing impaired and persons in wheelchairs. Respondents were sourced via mailing lists and social media channels. The committee of ethics of Ghent University has approved the study. The survey was self-administered and only majors participated.

Product dissatisfaction was measured using a single item measure, derived from Franke and Shah [23], and Stock, Von Hippel and Gillert [57]. Participants were asked to indicate on a 7-point Likert scale whether they agreed with the following statement: *I frequently have needs which are not covered by the products currently offered on the market.* To measure disability burden, we asked about the influence of the disability on a 7-point Likert scale where 1 = *little burden* and 7 = *extreme burden*. This measure is derived from a related study by Oliveira et al. [46].

We asked persons about their education, distinguishing between none, primary education, higher secondary education, higher non-university education (i.e. technical college) and university education. From this, we created a binary dummy variable, where higher non-university education and university education was coded as being an academic degree, with the remainder being non-academic.

3.2 Assessing Idea Quality

Several approaches exist to measure innovation. These may include measurement of traits associated with creative persons [3], or measuring the direct outcome of a creative process [25]. Considering the context of this study, we are most interested in the outcome of the ideation, i.e.: the concepts generated by our participants. To do so, defining metrics associated with innovative ideas is important. These may include variables such as quantity, quality, novelty, and variety of ideas [55].

In our case, we followed a frequently used two-step procedure to evaluate our participants' ideas [46]. Because our prompt for ideas was broad, it can be expected that participants submit concepts that cannot be considered. As a result, we had to remove all those comments that were obviously not valid. Examples of this include remarks about merely improving an existing product, or statements about better strategies to manage a disability. This process left 64 ideas, out of a total of 72. These 64 were subsequently presented to two judges not further involved in the research. Judges were given only a description of the idea. To help the judges contextualize the idea, they were additionally provided with details about the person's disability. Both of the judges were industrial designers with experience in research and design of assistive products. To measure the quality of ideas, we used the Consensual Assessment Technique (CAT)[2, 4]. This method is often applied in comparable studies on idea generation [12, 21, 35, 41, 43]). Usually, judges provide scores on one, or several, variables.

Typical variables are 1) originality, 2) user value and 3) producability [42] or 1) originality, 2) value, and 3) realization [34]. For our study, we asked the judges to evaluate ideas based on three attributes 1) originality, 2) user value and 3), feasibility. Scores were given on a 5-point scale, where 1 is the lowest possible score, and 5 the highest.

To assess the reliability of the scoring, we performed a Cronbach α analysis. Reliability was satisfactory, with idea originality at $\alpha = 0.722$, idea user value at $\alpha = 0.728$ and idea feasibility at $\alpha = 0.714$. As a result, we added the score for both judges across the three categories, to create the new variable: idea quality. The highest possible score is thus 30, with 6 being the lowest.

As part of our analysis, judges were also asked to indicate whether they think an idea may also be of value for persons without disabilities in a binary variable. Cohen's κ was run to determine agreement between the two judges about whether ideas could also be considered valuable for non-disabled persons. This binary variable is derived from De Jong et al. [31].

Results were satisfactory, $\kappa = 0.454$, ($p < 0,001$), which denotes "moderate" agreement [37]. Only when both reviewers positively judged an idea as also being valuable for persons without disabilities, did we denote it as such, resulting in 22 out of 64 ideas, 12% of our sample and 35% out of all submitted ideas.

4. DATA ANALYIS AND RESULTS

4.1 Descriptive Statistics

The average participant in our study was 42 years. Disability duration averaged almost 24 years. Our sample contained more women (N = 103) than men (N = 75), and degree of university education is close to 60%. From our sample, 12% are students; 36% employed while 52% are not currently in work. Slightly less than half are members of some community related to their disability. Assistive device use is high, with the majority (155, 87%) reporting that they use an assistive device.

Table 1 summarizes our Pearson Correlation Coefficients, 1-tailed significance. As might be expected, idea originality is negatively correlated with idea feasibility ($r = -0,41$; $p < 0,01$), a finding also reported by Kristensson et al. [34]. Additionally, dissatisfaction is significantly correlated with idea user value ($r = 0,5$ $p < 0,01$).

Table 2. General Demographic Data

Variable	S.D.	Mean	n	%
Age (years)	15,146	42,39		
Disability Duration (years)	18,107	23,74		
Male			75	42,10%
Female			103	57,90%
University Degree			106	59,60%
Employed			64	36,00%
Assistive Device User			155	87,10%
Member of an Community			86	48,30%

Dissatisfaction also shows a significant positive correlation with overall idea quality ($r = 0,54$; $p < 0,01$). This shows partial support for H_1. Academic degree holders show a significant positive correlation with idea originality ($r = 0,26$; $p = 0,02$). We note that disease burden and product dissatisfaction is positively correlated ($r = 0,34$; $p < 0.01$).

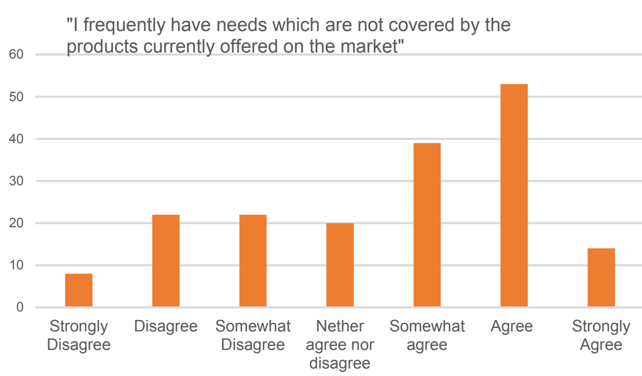

Figure 2. Degree of Product Dissatisfaction

Finally, we note that 38% of respondents either agree or strongly agree with the statement *I frequently have needs which are not covered by the products currently offered on the market,* with 60% falling into the group that somewhat agrees, agrees, or strongly agrees. This would support the assertion that product dissatisfaction is prevalent among disabled persons, and as Table 1 highlights, is positively correlated with disease burden.

4.2 Generated Ideas

To classify ideas, we used a categorization proposed by De Jong et al. [31]. This includes: (1) household fixtures or furnishing; (2) computer software; (3) vehicle-related; (4) food or clothing; (5) health, care or medical (6); tools or equipment; (7) sports, hobby or, entertainment; (8) any other items. This shows that a majority of the ideas (33%) are centered around the house, including suggestions to change furniture, entrances, etc. Secondly, suggestions related broadly to computer software (20%) feature prominently. Below we discuss some of these ideas in more detail.

Table 3. Categorization of Validated Ideas

	n	%
household fixtures or furnishing	21	33%
computer software	13	20%
vehicle-related	8	13%
food or clothing	8	13%
health, care or medical	6	9%
tools or equipment	3	5%
any other items	3	5%
sports, hobby or entertainment	2	3%

Several concepts were associated with mobility and accessibility. For example, a person traveling by public transport who needs extra assistance when embarking often needs to notify the driver well in advance when leaving a bus or tram. By providing travelers with a way to exit the bus without help, via an interface inside the bus, this could increase self-reliance. Similarly, one respondent describes having trouble with departing from the train at the right station, and wishes to have location information available digitally via a smartphone application, to help them depart at the appropriate time. While several respondents mention the idea for smaller GPS devices, one particular respondent wishes to have a proximity sensor that can be attached to clothing, to be notified when an obstacle is nearby. More low-tech ideas include mobile platforms that ease getting into and out of public transport, or into and out of the car.

In and around the home, several respondents propose ideas for further automation and remote control. One participant describes their goal of remote controlling – via Bluetooth – as many devices as possible, while another remarked that Near Field Communication (NFC) tags – in combination with a smartphone - could be used to open doors automatically. One visually impaired person proposes a keychain that stays in contact with your smartphone, which starts to vibrate when you are too far away from your keys, acting as an aid to not forget your home keys. Other interesting concepts include a tray that notifies its carrier when it is not being carried correctly, an unobtrusive wearable badge that functions as a dictation device, allowing speech instructions to be given, or a simple speaking watch that reads the time.

Several ideas also focus on improvements that are less high tech, such as toothpaste that only gives the appropriate amount when squeezed, or having a waterproof screen inside the shower, so someone can get in while the water is still warming up, without getting wet. One participant also describes regularly breaking plates and glasses by accident, and suggests changing the material of the dishware in order to avoid shards when breaking occurs, given that they pose a threat to the wheelchair tires.

Respondents also propose small changes to current assistive devices. This includes changes to crutches to have more grip during wet conditions, or simple modifications to a wheelchair allowing the user to carry – for example – an umbrella.

As noted earlier, we also asked our judges to indicate how relevant they perceive these ideas to be for non-disabled consumers, resulting in 22 ideas, 12% of our sample. These are related to more high tech or novel concepts, including automatic opening of doors, or more intensive use of speech recognition software.

4.3 Multiple Regression Analysis

To understand which characteristics are associated with good ideas, we performed a hierarchical multiple regression analysis, appropriate, given our single, continuous dependent variable, and our continuous and categorical independent variable.

For consideration into our model, we include the variables previously hypothesized as having a likely significant influence on overall idea quality: product dissatisfaction (H_1), use experience, measured through disease duration (H_2) and finally, a measure of benefit, disability burden (H_3).

Table 4. Linear Regression Model for Total Idea Quality

	Model I	**Model II**
	Unstandardized Coefficients	
	β (Stand error)	β (Stand error)
Constant	19,39** (1,14)	15,51** (1,52)
Independent Variables		
Disability Duration		0,02 (0,01)
Disability Burden		-0,07 (0,20)
Dissatisfaction		0,82** (0,17)
Control Variables		
Gender [a]	0,18 (0,63)	0,08 (0,54)
Academic Degree [b]	1,62* (0,69)	1,45* (0,59)
Model fit		
R^2	0,09	0,38
p-value	0,07	<0,01

a: male as reference category
b: no academic degree as reference category
** = p < 0.05, * = p < 0.1

Our dependent variable, idea quality, consists of the total score given for each idea across the three measured idea variables (user value, feasibility and originality), summed for both judges. A concern when performing regression analysis is multicollinearity. Variance influence factor (VIF) was calculated and was below 2, well below the recommended level of 10 [11]. Visual inspection of the normal probability plot and scatter plot also reveal no issues related to normality and outliers.

Following related studies, we control for both gender [33, 54] and academic status [32]. As a result, we first present a control model, Model I, followed by Model II, where we include our three independent variables. All coefficients are unstandardized.

Model I first presents results where we only consider our control variables, gender and academic degree. The model significance was unsatisfactory: $F(2,59) = 2,84$, $p = 0,07$, $R^2 = 0,09$. Additionally, as indicated by our R^2 statistic, which explains the variance idea quality accounted for by the model, Model I explains little variance suggesting that any effects of gender ($\beta = 0,18$; $p = 0,78$) and academic degree ($\beta = 1,62$; $p = 0,02$) are low.

Next, for Model II, we added our three independent variables, disability duration, disability burden and product dissatisfaction. Model II's performance is better: $F(6,56) = 6,78$; $p < 0,01$; $R^2 = 0,38$.

As Table 4 shows, dissatisfaction has a significant positive effect on idea quality ($\beta = 0,82$; $p < 0,01$), leading to support for H_1. However, our proxy measure for use experience, disability duration ($\beta = 0,02$; $p = 0,23$), fails to reach significance level, leading us to reject H_2. Finally, disability burden, our measure of benefit, also fails to have any effect on idea quality ($\beta = -0,07$; $p = 0,73$), leading to rejection of H_3. Finally, while gender ($\beta = 0,08$; $p = 0,78$) in Model II does not have any significant effect on idea quality, academic degree ($\beta = 1,62$ $p = 0,02$) has a significant positive influence when added to the model as part of our three independent variables.

5. DISCUSSION

Given the low product satisfaction of persons with disabilities, user innovation theory suggests that disabled persons may be valuable candidates as product innovators. To explore this assumption, we performed a survey among disabled persons (N = 178), asking them to describe ideas for products. With the help of two independent judges, we scored the quality of the ideas based on user value, feasibility and originality. We performed a hierarchical multiple regression to assess whether and which of our hypothesized lead user characteristics influence overall idea quality.

Results indicated that of the three characteristics explored, only dissatisfaction has a significant impact on idea quality. These results emphasize the earlier findings in the user driven innovation literature that persons who are dissatisfied with current products can be valuable product innovators. We also stress that persons with an academic degree will be more likely to innovate, which also reflects previous studies on user innovation.

However, our two remaining indicators, use experience, as indicated through disability duration, and disease burden – as measure of benefit - fail to have an impact on idea quality. Model II, while significant, explains only 38% of the variance, suggesting that other, unmeasured attributes may additionally provide insights into the characteristics associated with innovative disabled persons.

Additionally, we made use of proxy indicators to measure use experience and framed disability burden as a measure of benefit. Such proxy indicators may not have accurately reflected our hypothesized lead user characteristics.

A further relevant finding as part of this survey is that ideas generated by persons with disabilities – often in the context of their particular disability – can be valuable to non-disabled persons. Design approaches such as 'design for all' or 'universal design' - where products are not necessarily adapted for persons disability, - but instead designed to include as many users as possible [30], have seen increased attention as designers strive for barrier free use. As noted earlier, the increased needs felt by disabled persons, combined with their product dissatisfaction – as noted here and in other studies – may suggest they may have a potential valuable role as product ideators above and beyond the design of assistive devices. While we find no significant correlations between any of our dependent variables on the likelihood of persons coming up with ideas that have potential beyond assistive devices, this data would suggest that these users may form a valuable – and little researched – cohort of product ideators.

The current work contributes to our understanding of the characteristics of user innovators, most notably of persons with disabilities. These results are thus relevant for persons hoping to gather ideas from disabled persons or involve them in product ideation.

When reflecting back on the low rates of product satisfaction experienced by disabled persons (also captured in this study), combined with significant amounts of persons who have ideas for new products, we note that there has thus far been little attention to involving disabled persons as ideators.

6. LIMITATIONS AND FUTURE WORK

First, while our reviewers were knowledgeable about the design of assistive products, neither have medical expertise, and as a result, medical professionals may evaluate submitted ideas differently. Additionally, our method of evaluating ideas has been well established and is widely used in related research [12, 21, 35, 41, 43]), but does not take into account the value of the idea on a long term basis and neither does it consider long term commercial viability. The current study also focusses on ideas as opposed to developed products. While ideas often precede products [5, 26, 58], they do not require (technical-) knowledge that support realization, and may subsequently be associated with different user characteristics. Our lack of physical prototypes – while not uncommon in studies of this type – also restricts the judges' ability to evaluate result. As result, it my may be valuable to also judge developed products, perhaps also by average non-disabled consumers, or even peers.

Second, while 12% of participants submitted ideas that were also relevant for non-disabled users, the current study does not take into account the rate of product ideation between persons with and without disabilities. Our study thus finds support for the existence of ideating users among disabled persons, but we cannot claim that the incidence of ideation is higher - when compared to a non-disabled population, or that the quality, novelty or feasibility is significantly different. Furthermore, for the 12% of participant submitted ideas that were also scored as relevant for non-disabled users, it remains unclear whether average consumers would also view these ideas as relevant.

We recruited participants through online media channels of organizations for disabled persons. This may consist out of a cohort of people that are already active and engaged, which may result in exaggerated view on the degree to which persons have ideas for new products.

Model II reveals a R^2 value of 0,38. From this follows that 38% of the variance in our outcome variable is explained by our measured independent variables. Other characteristics not included in this study may more accurately measure the degree user generated ideas.

Given these limitations, we suggest that future efforts could be focused on measuring alternative user characteristics that could be associated with user innovators such as innovative personalities [54], being an early adopter [7], or creativity [24].

Most crucially, we expressly limited our study to persons with disabilities. While this study indicates that the lead user theory is also applicable among disabled persons, we cannot claim that disabled persons are any better at idea generation than non-disabled persons. A study directly comparing these cohorts could be valuable to establish whether differences exist.

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